The Role of Lean in Enhancing Operational Performance Through Sustainability and Supply Chain Practices: A Case Study on the Automotive Industry

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Abstract

Globalization, increasing awareness of environmental issues, and advances in technology have forced manufacturing industries to adopt new and innovative practices to navigate these unprecedented challenges. Accordingly, companies started to reassemble their distinctive capabilities and supply chain practices to reach customers from different geographical locations, increase profits, expand sourcing opportunities, and offer a wide selection of services and products. At the same time, firms started to implement lean tools, which are tools that eliminate wastes in the value chain, such as Just-In-Time (JIT), 5S, seven wastes, and Kanban. While previous studies asserted the significance of implementing lean tools while improving current supply chain and sustainability practices, there has been little investigation on the interaction of the three, and their intertwined effect on operational performance. Therefore, the purpose of this paper is to explore the link between lean manufacturing, supply chain practices and sustainability practices, and their impact on operational performance metrics. A survey questionnaire was developed based on previous literature and practitioners' feedback and sent to 94 American and European Automotive facilities. The results generated from the pilot study revealed that there is a significant correlation between lean, supply chain and sustainability practices, and operational performance ($p < .05$). Moreover, the data indicated that lean manufacturing, through planning, sourcing, and production constructs enhances delivery, efficiency, and quality ($p < .05$). In addition, supply chain practices, when coupled with sustainability, had a significant positive effect on operational performance ($p < .001$) while at a time, sustainability practices were found to have a significant mediating effect on the lean-performance relationship ($p < 0.001$).

Keywords
Lean Manufacturing Systems, Supply Chain Practices, Sustainability Practices, Operational Performance, Response Surface Analysis.

1. Introduction

In the past few decades, firms from different industries are implementing lean practices to gain a competitive edge against their competitors, increase productivity, and reduce wastes (Womack and Jones, 2003). Lean is defined as the ability of the organization to identify and eliminate wastes throughout the value chain (Agarwal et al., 2006). Many scholars consider lean as an essential tool for the success of any manufacturing firm (Selko, 2012).

Although lean has proved to be a successful model over the years, some discrepancies existed in its implementation. One of the issues that manufacturing firms faced was the failure to sustain and improve their results over the long term (Lucey et al., 2005), which has created an increased interest among scholars to investigate the underlying reasons behind the inability to sustain the results.

Moreover, the rising concerns on the environment, and especially on the effects of climate change, have led manufacturing industries to adopt sustainable behaviors in the manufacturing process. Organizations consider sustainable manufacturing and circular economy essential for survival in the competitive market (Bevilacqua et al., 2007). However, several challenges may arise in implementing sustainability practices, such as the complexity of supply chains and high setup costs (Jaeger and Upadhyay, 2020). These challenges can be overcome through the adequate implementation of lean manufacturing tools. The proper implementation of lean tools through sustainability practices may result in achieving better sustainable behaviors and performance (Martínez-Jurado and Moyano-Fuentes, 2014).

Furthermore, to gain the full benefits of lean tools, the organization should not only implement them within the organization but should also integrate them throughout the supply chain (Hines et al., 2014). The implementation of lean tools through supply chain practices will be a great enabler for any firm that strives to improve its operational performance (Myerson, 2012). Manufacturing firms within a lean supply chain can deliver a better customer experience, enhance the quality and delivery of their products and services, respond faster to customers' needs, and improve overall efficiency.

Various articles have examined the interaction between lean, supply chain practices, sustainability, and operational performance. However, most of these studies were limited in selecting the metrics and/or limited to a specific industry. Therefore, this paper aims to investigate the link between lean manufacturing, supply chain practices, and sustainability practices and their impact on the automotive industry operational performance metrics. Based on that, a survey questionnaire was developed and sent to 94 American and European Automotive facilities.

The remainder of the paper is organized as follows: Section 2 presents the literature review and hypotheses development. Section 3 discusses the research methodology and data collection. Section 4 details the results and their analysis. Section 5 presents the discussion and the conclusions of the study are presented in section 6.

2. Literature Review and Hypotheses Development

2.1. Lean Manufacturing

Lean manufacturing is the ability of the organization to eliminate non-value-added activities in the manufacturing process (Shah and Ward, 2003). Lean manufacturing contributes to the conservation of scarce resources (Chugani et al., 2017). Several lean tools are used in the waste elimination process to achieve operational excellence, such as 5S, Kaizen, Kanban, and 7 wastes (Li et al., 2005). Kaizen is a concept referred to as the continuous improvement of manufacturing processes. As for the 5S, the first S is sort, and it entails removing unnecessary parts, materials, and tools. The second S is set-in-order, and it involves identifying and arranging parts and tools for ease of use. The third S is shine, and it implies cleaning the area where the work is done. The fourth S is standardize, and it indicates setting up standards for all best practices. The last S is sustain, and it is the ability to form a habit by following the first four S. Kanban is a framework that enables manufacturing firms to have real-time communication of the information they need through workflow management. Kanban covers four principles: Visualize workflow, limit work-in-progress, focus on flow, and continuous improvement; while the seven sources of waste are: inventory, defects, waiting, overproduction, motion, over-processing, and transportation.

2.1.1. Lean Manufacturing and Operational Performance

Lean manufacturing tools improve several performance metrics such as cost, quality, delivery, efficiency, among others. Depending on various factors such as industry type, some of the lean tools might enhance one metric more than the other. Pérez-Pucheta et al. (2019) examined the effect of lean tools in the automotive industry. Their result indicated that the use of value stream mapping and the A3 report reduced the delivery time. Zhou (2016) investigated the factors associated with the implementation of lean in small and medium-sized enterprises in the US, and his study revealed that lean tools enhanced delivery and quality and reduced delivery times. Other studies also showed that lean tools improve productivity (Das et al., 2014; El-Khalil, 2018; Dave and Sohani, 2019; Singh et al., 2018), quality (Anvari et al., 2011; Chowdary and George, 2012; Garza-Reyes, 2012), efficiency (Indrawati et al., 2019; D'Antonio et al., 2017; Agus and Shukri Hajinoor, 2012; El-Khalil 2020), and delivery time (Deshmukh and Upadhye, 2010; Wong et al., 2014; Rahman et al., 2010).
Therefore, the following hypothesis is derived:
H1: Lean manufacturing has a positive effect on operational performance.

2.1.2. Lean Manufacturing and Sustainability

Previous literature has shown that lean practices improve the dimensions of the triple bottom line (TBL) (Bauer et al., 2018; King and Lenox, 2001). TBL dimensions are economic, social, and environmental, and their practices are shown in table 1 (Yusuf et al., 2013; Golicic and Smith, 2013; El-Khalil and Mezher, 2020; Paulraj et al., 2017; Wong et al., 2012; Chin et al., 2015; Sarkis et al., 2010).

Table 1. Sustainability dimensions and practices

Sustainability Dimensions	Sustainability Practices
Society	The company ensures product safety
	The company complies with the law
	The company treats suppliers fairly
	The company has good community relations
	The company respects human rights
	The company has good working conditions
Economy	The company continuously create jobs
	The company works on enhancing anti-bribery and corruption policies
	The company pays all the taxes responsibly
	The company supports, creates, and drives innovative ideas
	The company generate sales and profits
	The company invest in the local community
	The company invest in the infrastructure
Environment	In the production/manufacturing process, the company minimize the use of hazardous substances
	In the production/manufacturing process, the company minimize wastes and emissions
	The company use alternative and renewable energies
	The company works toward protecting biodiversity
	The company uses energy resources efficiently

Furthermore, prior studies have shown that implementing both lean and sustainability practices improves performance (Gandhi et al., 2018). Lean tools achieve economic sustainability through reducing costs and resources, social sustainability through ensuring the safety and health of employees, and environmental sustainability through eliminating wastes and preserving scarce resources (Bae and Kim, 2008). As stated by Rothenberg et al. (2001), ''Sustainability dimension is inseparable of lean, since reducing energy consumption and preserving the environment is one of the ultimate longtime waste reductions". While other authors such as Bidarianzadeh and Fortune (2002) states that lean main goal is to eliminate waste and maximize customer value and satisfaction whereas going green does not fall within its main objectives.
Accordingly, the following hypotheses are derived:

H1a, H1b and H1c: Sustainability practices mediate the relationship between lean manufacturing and operational performance (a: Quality, b: Delivery, c: Efficiency).

2.2. Supply Chain Management

Supply chain management is the network of different business units that coordinates and works with each other to deliver the final product or service to the end customer (Wang and Song, 2017). The success of any organization in today's competitive market depends on the robustness and flexibility of its supply chain (Delic and Eyers, 2020; El-khalil & Nader, 2020). Table 2 summarizes some of the authors' definitions of the supply chain.

Table 2. Supply Chain definition by various authors

Authors	Definition
Jones and Riley (1985)	An integrative approach to dealing with the planning and control of the materials flow from suppliers to end-users.
Ellram (1991)	A network of firms interacting to deliver product or service to the end customer, linking flows from raw material supply to final delivery.
Christopher (1992)	Network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer.
Lee and Billington (1992)	Networks of manufacturing and distribution sites that procure raw materials, transform them into intermediate and finished products, and distribute the finished products to customers.
Berry et al. (1994)	Supply chain management aims at building trust, exchanging information on market needs, developing new products, and reducing the supplier base to a particular OEM (original equipment manufacturer) so as to release management resources for developing meaningful, long term relationship.
Saunders (1995)	External Chain is the total chain of exchange from original source of raw material, through the various firms involved in extracting and processing raw materials, manufacturing, assembling, distributing and retailing to ultimate end customers.
Kopczak (1997)	The set of entities, including suppliers, logistics services providers, manufacturers, distributors and resellers, through which materials, products and information flow.
Lee and Ng (1997)	A network of entities that starts with the suppliers' supplier and ends with the customers' custom the production and delivery of goods and services.
Tan et al. (1998)	Supply chain management encompasses materials/supply management from the supply of basic raw materials to final product (and possible recycling and re-use). Supply chain management focuses on how firms utilize their suppliers' processes, technology and capability to enhance competitive advantage. It is a management philosophy that extends traditional intra-enterprise activities by bringing trading partners together with the common goal of optimization and efficiency.

2.2.1. Supply Chain Practices and Operational Performance

The strength of the supply chain practices can be measured through several metrics. As shown in table 3, supply chain practices can be divided into planning, sourcing, delivery, and production (Gunasekaran et al., 2001; Ganeshan et al., 2001; Fleisch and Tellkamp, 2005; Trkman et al., 2010; Jabbour et al., 2011).

Table 3. Supply Chain practices

Latent Variable/Construct	Dimensions	Number of manifest variables
Planning Practices	Order Planning	6
	Tactical Planning	6
	Inventory Strategy	4
Sourcing Practices	Strategic	2
	Tactical	5
	Operational	1
Delivery Practices		9
Production Practices	Make	6
	Assembly	3
	Packaging	2

Numerous authors examined the effect of supply chain practices on operational performance. Most of the studies found a positive impact of planning practices (Peterson et al., 2005), sourcing practices (Khan and Pillania, 2008; Kumar et al., 2003; Ellram and Carr, 1994; Pearson and Gritzmacher, 1990), delivery practices (Beamon, 1999; Khan et al., 2009), and production practices (Cankaya and Sezen, 2019) on operational performance.
Therefore, the following hypotheses are formulated:
H2, H3 and H4: Supply chain practices (H2: Planning, H3: Sourcing, H4: Production) have a positive impact on operational performance.

2.2.2. Supply Chain Practices and Sustainability

To achieve more sustainable and profitable performance, firms from different sectors are trying to incorporate sustainability practices within their supply chain (Zhu et al., 2008). In the sustainable supply chain, organizations aim to enhance the employees' welfare and safety (social), reduce the environmental impact of their manufacturing process (environmental), and achieve better economic outcomes (economic) (Crum et al., 2011; Correia et al., 2017; Martínez-Jurado and Moyano-Fuentes, 2014).
Accordingly, the following hypotheses are formulated:
H2a, H2b and H2c: Sustainability mediates the relationship between supply chain practices, namely Planning Practices, and operational performance.
H3a, H3b and H3c: Sustainability mediates the relationship between supply chain practices, namely Sourcing Practices, and operational performance.
H4a, H4b and H4c: Sustainability mediates the relationship between supply chain practices, namely Production Practices, and operational performance.

2.2.3. Supply Chain Practices and Lean Manufacturing

The concept of supply chain revolves around the ability of the organization to coordinate the work in the value chain, and for better coordination, organizations should focus on eliminating wastes (Womack and Jones, 1996). From the waste management perspective, lean tools provide flexibility in the supply chain, leading to better identification and elimination of unnecessary activities (Manrodt et al., 2005). Moreover, lean flow is the ability of the organization to move the product from the manufacturing phase to the delivery phase as soon as possible (Womack and Jones, 2003). Lean flow can enhance the supply chain coordination since both of them aim to have a smooth and efficient process within the manufacturing firms (Manrodt et al., 2005). Also, supply chain practices might play a mediating role between lean and operational performance metrics (Alqudah et al., 2020).
Therefore, the following hypotheses are derived:
H5, H6 and H7: Lean manufacturing has a positive impact on supply chain practices (H5: Planning, H6: Sourcing, H7: Production).
H5a, H5b and H5c: Supply chain practices, namely Planning practices, mediate the relationship between lean manufacturing and operational performance.
H5a, H5b and H5c: Supply chain practices, namely Sourcing practices, mediate the relationship between lean manufacturing and operational performance.
H5a, H5b and H5c: Supply chain practices, namely Production practices, mediate the relationship between lean manufacturing and operational performance.

3. Research Methodology and Data collection

The data used for the present analysis was collected from American and European Automotive facilities. A survey questionnaire was developed based on previous literature and practitioners' feedback. First, during the conceptualization phase, the scales used in the survey were amended by selected researchers and managers in a way to align the questions with the main objectives of the study. Then, the survey was sent to 94 senior managers in American and European automotive facilities and virtual interviews and/or follow-up emails were conducted to gather all required information. The survey consists of two parts. The first one covers general demographical questions, such as age, gender, level of experience, etc. The second part includes the 18 mostly used Lean Manufacturing tools, three main constructs of supply chain practices (Production, Sourcing, Planning) with 3 dimensions each (Table 3) and three operational performance metrics (OPMs) which are Quality, Delivery and Efficiency. Additionally, sustainability practices were measured through 28 questions related to the three dimensions: economic, social and environmental. The items were measured using a seven-point Likert scale where 1 was defined as "not applicable" and 7 as "applicable". To analyze the collected data, two software were used: Statgraphics (Centurion 18, Windows XP) and SPSS (IBM SPSS Statistics 26).

To test the reliability and validity of the measurement scale, many statistical measures such as Cronbach's α, composite reliability (CR) and average variance extracted (AVE) were calculated. Since the supply chain dimensions are numerous and include several manifest variables while at a time sustainability practices and lean manufacturing systems are multi-dimensional, parceling method (Nader et al., 2016) was used to convert them into latent variables. Further to generating the main descriptive statistics relative to each variable, SPSS was used for hypothesis testing and path analysis. Then, to confirm the presence of mediators in the model, a Sobel test was applied measuring t-statistics and p-values. Additionally, a polynomial regression modeling coupled with response surface analysis were conducted using Statgraphics. The Standardized Pareto Charts illustrate the significant factors affecting the OPMs. The main effects plots indicate the linear effects of the variables and the response surfaces were generated and plotted between the two most significant parameters. Such surfaces exemplify the trend of variation of each OPM within the studied test range. Finally, these three different graphical representations facilitate the visualization of the hypothesized direct and mediating (indirect) effects.

4. Results Analysis

4.1. Measurement model: convergent and discriminant validity, and reliability analysis

As a first step, multiple tests were applied to confirm the validity and the reliability of the measurement model. These were evaluated by testing item loadings, Cronbach's α, composite reliability (CR) and average variance extracted (AVE). The loadings between the constructs and their measures were higher than the threshold of 0.7 (EL-Khalil, 2018; Panwar et al., 2018; Yunis et al., 2017; Yunis et al., 2018; El-Kassar et al., 2020; El-Kassar et al., 2014). This proves an acceptable reliability of the scales for all reported measurements. Discriminant validity was tested by comparing AVE and CR to the inter-constructs correlation values. Since all AVE and CR values were greater than the squared correlations between the constructs, the discriminant validity of the model was then confirmed. In addition, the convergent validity was concluded from AVE values that were all higher than 0.5 (El-Khalil and Mezher, 2020; El-Khalil et al., 2020; El-Khalil and Darwish, 2019; El- Kassar and Singh, 2019; Jaafar et al., 2020).

Table 4. Correlation matrix

	Planning	Sourcing	Production	Lean	Sustainability	Delivery	Efficiency	Quality
Planning	-							
Sourcing	0.82**	-						
Production	0.82**	0.82***	-					
Lean	0.82**	0.81**	0.81**	-				
Sustainability	0.81**	0.8**	0.8**	0.83***	-			
Delivery	0.76*	0.75*	0.75*	0.77*	0.8**	-		
Efficiency	0.77*	0.78**	0.77*	0.8**	0.81**	0.74*	-	
Quality	0.77*	0.76*	0.76*	0.8**	0.81**	0.76*	0.77*	-

*Note: *p < .05 **p < .01 ***p < .001*

4.2. Assessment of the fitted models

The coefficient of determination (R^2) of all generated polynomial regression models exceeded 85% and the p-value for the lack of fit in the analysis of variance (ANOVA) was higher than 0.05 meaning that the models appear to be adequate for the observed data at the 95.0% confidence level. In fact, the R^2 ranged between 87.7% and 91.3%, meaning that the models as fitted explain 88 to 91% of the variability in OPMs. Furthermore, the estimated results of the dependent variables showed no significant differences between the observed and fitted values. This demonstrates that the equations of the fitted models reflect the reality and can be adequately applied to predict OPMs by varying the constructs (the studied independent variables) within the test range (Nader et al., 2017; Nader et al., 2018; Nader et al., 2021; Nader et al., 2016; El-Kassar et al., 2017). Additionally, correlation matrix was displayed to analyze the relationships and interdependencies between the latent variables. The Pearson product-moment correlation matrix showed high and significant (*p-value < .05)* correlations between the supply chain practices (planning, sourcing, and production), lean manufacturing tools, sustainability practices and the studied OPMs (delivery, efficiency and quality). The results were demonstrated in Table 4. The correlation coefficients were all below 90% confirming the absence of any common method bias (El-Khalil, 2015; El-Khalil and El-Kassar, 2018; El-Kassar et al., 2020; El-Gammal et al., 2020). The constructs were positively correlated with each other and with the OPMs as well. The strongest correlation was between lean and sustainability (0.83) while the lowest one was observed between delivery and efficiency (0.74).

Further to exploring the basic statistics describing the variables and their correlation, a path analysis and polynomial regression modeling were performed to test the suggested hypotheses. After testing the direct effects of all the constructs on the OPMs, it was concluded that Planning, Sourcing, Production, Lean and Sustainability practices positively affect the efficiency, the quality and the delivery performance of the automotive firms (*p-values < .001)*. However, the primary objective of this study is to check if Supply Chain and Sustainability practices have a mediating effect by strengthening these relationships and boosting the performance. Therefore, path coefficients and Sobel-test statistics were determined to depict any possible mediation effect. In this context, direct and indirect effects were obtained with and without inclusion of the mediator to be studied. The increase or decrease of the relationship value will explain the role of the mediator in the model. When studying the indirect effects for each path structure, the obtained values cover the relations between the construct and the mediator, the mediator and the OPM and the effect of the latent variable associated with the mediator on the OPM. Furthermore, a Sobel test was mainly utilized to determine if the mediator can significantly affect the relationship between the construct and the dependent variable. Test statistics higher than 1.96 and p-values lesser than 0.05 for a 95% confidence level can confirm the mediating role of the studied construct (EL-Khalil, 2018).

The analysis of the results illustrated in Table 5 shows that the direct effects of Lean tools on OPMs without the mediator were 1.17, 1.14 and 1.12. These were much higher than the values observed after including the SUS practices as a mediator (0.033, -0.17, 0.026, respectively). The latter relationships became insignificant and SUS was found to be highly affecting OPMs, showing that hypotheses H1 (a, b, c) were supported. This specifies that the mediator associated to Lean improves the performance of the firm. Same results were found for the Hypotheses 2 (a, b, c), 3 (a, b, c) and 4 (a, b, c) where the sustainability was the mediator between supply chain practices and OPMs. In addition, the mediating effect of supply chain practices on the Lean-OPMs relationships was only supported for the following hypotheses: H5 (a, b, c), H6 (c), and H7 (c). Contrariwise, the mediating effects of Sourcing and Production on the Lean-Quality and Lean-Delivery relationships were rejected since Sobel test statistics were 1.51, 1.59, 1.56 and 1.83 for H6-a, H6-b, H7-a and H7-b, respectively with p-values greater than 0.05.

Table 5. Mediation analysis

Hypotheses	Direct effect without Mediation variable	With mediation variable		Sobel test statistics	Decision (Supported)
		Path	Std. error		
H1-a	Lean → Quality (1.17***)	Lean → Quality (0.033)	0.17	6.97 (p-value < 0.001)	Supported
		Lean → SUS (1.23***)	0.023		
		SUS → Quality (0.92***)	0.13		
H1-b	Lean → Delivery (1.14***)	Lean → Delivery (-0.17)	0.18	7.24 (p-value < 0.001)	Supported
		Lean → SUS (1.23***)	0.023		
		SUS → Delivery (1.06***)	0.14		
H1-c	Lean → Efficiency (1.12***)	Lean → Efficiency (0.026)	0.15	7.23 (p-value < 0.001)	Supported
		Lean → SUS (1.23***)	0.023		
		SUS → Efficiency (0.89***)	0.12		
H2-a	Planning → Quality (0.95***)	Planning → Quality (0.15)	0.09	8.72 (p-value < 0.001)	Supported
		Planning → SUS (0.99***)	0.03		
		SUS → Quality (0.81***)	0.09		
H2-b	Planning → Delivery (0.93***)	Planning → Delivery (0.06)	0.1	8.69 (p-value < 0.001)	Supported
		Planning → SUS (0.99***)	0.03		
		SUS → Delivery (0.87***)	0.1		
H2-c	Planning → Efficiency (0.91***)	Planning → Efficiency (0.09)	0.08	9.84 (p-value < 0.001)	Supported
		Planning → SUS (0.99***)	0.03		
		SUS → Efficiency (0.83***)	0.08		
H3-a	Sourcing → Quality (0.91***)	Sourcing → Quality (0.03)	0.08	10.67 (p-value < 0.001)	Supported
		Sourcing → SUS (0.96***)	0.03		
		SUS → Quality (0.92***)	0.08		
H3-b	Sourcing → Delivery (0.89***)	Sourcing → Delivery (0.00)	0.09	9.93 (p-value < 0.001)	Supported
		Sourcing → SUS (0.96***)	0.03		
		SUS → Delivery (0.93***)	0.1		

H3-c	Sourcing → Efficiency (0.9***)	Sourcing → Efficiency (0.2**) Sourcing → SUS (0.96***) SUS → Efficiency (0.7***)	0.07 0.03 0.07	9.42 (p-value < 0.001)	Supported
H4-a	Production → Quality (0.94***)	Production → Quality (0.07) Production → SUS (0.99***) SUS → Quality (0.89***)	0.08 0.031 0.08	10.46 (p-value < 0.001)	Supported
H4-b	Production →Delivery (0.93***)	Production → Delivery (0.05) Production → SUS (0.99***) SUS → Delivery (0.89***)	0.09 0.031 0.09	9.50 (p-value < 0.001)	Supported
H4-c	Production→Efficiency (0.92***)	Production → Efficiency (0.16*) Production → SUS (0.99***) SUS → Efficiency (0.76***)	0.08 0.031 0.07	9.93 (p-value < 0.001)	Supported
H5-a	Lean → Quality (1.17***)	Lean → Quality (0.79***) Lean → Planning (1.15***) Planning → Quality (0.33**)	0.13 0.03 0.11	2.90 (p-value <0.001)	Supported
H5-b	Lean → Delivery (1.14***)	Lean → Delivery (0.8***) Lean → Planning (1.15***) Planning → Delivery (0.3*)	0.15 0.03 0.13	2.38 (p-value <0.05)	Supported
H5-c	Lean → Efficiency (1.12***)	Lean → Efficiency (0.84***) Lean → Planning (1.15***) Planning → Efficiency (0.24*)	0.13 0.03 0.11	2.31 (p-value < 0.05)	Supported
H6-a	Lean → Quality (1.17***)	Lean → Quality (0.99***) Lean → Sourcing (1.17***) Sourcing → Quality (0.15)	0.13 0.034 0.10	1.51 (p-value 0.1)	Not Supported
H6-b	Lean → Delivery (1.14***)	Lean → Delivery (0.93***) Lean → Sourcing (1.17***) Sourcing → Delivery (0.18)	0.14 0.034 0.11	1.59 (p-value 0.1)	Not Supported
H6-c	Lean → Efficiency (1.12***)	Lean → Efficiency (0.72***) Lean → Sourcing (1.17***) Sourcing → Efficiency (0.34***)	0.11 0.034 0.09	3.71 (p-value < 0.001)	Supported
H7-a	Lean → Quality (1.17***)	Lean → Quality (0.98***) Lean → Production (1.14***) Production → Quality (0.17)	0.13 0.03 0.11	1.56 (p-value 0.1)	Not Supported
H7-b	Lean → Delivery (1.14***)	Lean → Delivery (0.89***) Lean → Production (1.14***) Production → Delivery (0.22)	0.14 0.03 0.12	1.83 (p-value 0.06)	Not Supported
H7-c	Lean → Efficiency (1.12***)	Lean → Efficiency (0.8***) Lean → Production (1.14***) Production → Efficiency (0.29***)	0.12 0.03 0.1	2.89 (p-value <0.001)	Supported

5. Discussion

This paper focuses on studying the relationship between Supply Chain, sustainability practices, lean manufacturing systems (LMS) and their impact on the studied OPMs. Results showed that not all hypotheses were supported. Specifically, not all SC practices (planning, sourcing, and production) have a mediating effect on all Lean-OPMs relationships (H6a, H6b, H7a and H7b, table 5, figure1). In fact, hypothesis 1 was supported where Sustainability practices mediates the relationship between: (a) LMS and quality, (b) LMS and delivery, (c) LMS and efficiency. The results also showed that sustainability practices when coupled to SC practices will improve the quality, delivery and efficiency performance of the automotive firms (H2-a, b, c, H3-a, b, c, H4-a, b, c were supported). Hypothesis 5 was supported where Planning mediates the relationship between: (a) LMs and quality, (b) LMS and delivery, (c) LMS and efficiency. On the other hand, hypotheses 6-a and 6-b (i.e. sourcing mediates the relationship between LMS and quality, and between LMS and delivery, respectively) were not supported. However, hypothesis 6-c was supported indicating that sourcing mediates the link between LMS and efficiency. Same results were found regarding the mediating effect of Production on LMS-OPMs relationships. Figure 1 illustrates selected findings of each hypothesis elaborated in this paper.

5.1. Sustainability as mediator between LMS and OPMs.

Based on Table 5 and Figure 1, results showed that the direct effect of LMS affected positively the studied OPMs. This slope became insignificant when SUS practices were introduced. When implementation of SUS practices were very limited, the quality performance remains almost stable while increasing the use of multiple lean tools. However, when effective SUS practices are coupled with a fully operational LMS, the trend of the performance drastically increases. In fact, waste reduction and prevention of the defected products, one of the main mutual practices of lean manufacturing and economic and environmental sustainability, can improve the quality performance of any firm (Chowdary and George, 2012; Garza-Reyes, 2012; Ghosh, 2012), its productivity and efficiency. In addition, in LMS, work functions are performed in the same standardized sequence to safely and efficiently achieve quality and productivity standards. Furthermore, the concurrent implementation of good LMS and SUS practices would accentuate the on time delivery at minimum cost with a good productivity and quality, and therefore the firm would be able to efficiently satisfy and respond to all customers' demands (Vanichchinchai, 2019).

5.2. Sustainability as mediator between Supply chain practices and OPMs.

The results show that the direct effects of Supply chain practices on quality, delivery and efficiency performance are significant (*p-value* $< .001$). Based on the Standardized Pareto Charts and the Main Effects Plots, planning, sourcing, production without the mediation variable showed an important increase in the performance. However, when sustainability practices were implemented, the effects of these Supply Chain constructs became insignificant and the mediator shows a stronger relationship. For instance, at low levels of SUS implementation, and while applying sourcing, the efficiency scarcely increased from 3.4 to 4.4. However, at high level of SUS implementation, the efficiency reached its apex of 7. This shows that sustainability practices has a mediating effect on the Supply Chain Practices-OPMs relationships.

Results were in alignment with those found in the literature. The findings stand with the idea of using sustainability practices in the supply chain (Cousins et al., 2019). In fact, the adoption of a green supply chain management improves the product quality and delivery time (Geng et al., 2017; Mani et al., 2018). Additionally, the synchronized implementation of these practices can minimize the obstacles in the supply chain and the overall lead time through cross-functional teams, improving by that the efficiency and the productivity of the firms. In addition, manufacturing companies having green and sustainable production, distribution, packaging, planning and sourcing practices can use their resources in an efficient manner. This can reduce the cost incurred by industries, improve their productivity (Luthra et al., 2016; Vijayvargy et al., 2017; Yildiz Çankaya & Sezen, 2019), and lead to higher supply chain resilience while gaining a better competitive advantage and staying viable in the challenging market.

5.3. Planning, Sourcing, Production as mediators between LMS and OPMs

Table 5 shows the results of the mediation analysis of SC practices on the relationship between LMS and OPMs. By focusing on the direct effect of LMS on OPMs without the presence of the mediator, results showed that the implementation of LMS alone increases significantly the quality (β 1.17, $p < .001$), the delivery (β 1.14, $p < .001$) and the efficiency performance (β 1.14, $p < .001$) (Table 5, Figure 1). Same results were found by Panwar et al., (2018) and Henao et al., (2019) concluding that lean tools positively impacted the operational performance and improved the quality. The application of LMS in the industries can reduce the waste, the defected products, delivery time, and cost while increasing the productivity. The Standardized Pareto Charts showed that LMS without the presence of a mediator has a significantly positive effect on the quality (H5-a) at 95% confidence level. Yet, while introducing the Planning practices, LMS effect was slightly reduced but stayed significant while the implementation of both constructs largely increased the quality performance. The response surface elucidates this finding and clearly shows the partial mediation effect. When scarce implementation of planning practices is conducted, and by increasing the Lean practices, the quality performance marginally improves. However, when the application of planning practices is at its highest level, and when LMS tools are intensively put in practice, the slope of the increasing trend of variation in quality performance was much bigger and the performance indicator could reach its highest value of around 7.

Contrariwise, the direct effect of LMS on delivery (β 1.17, $p < .001$) and quality (β 1.17, $p < .001$), without implementing sourcing or production, was positive and highly significant. As for the indirect effect, the standardized coefficient of LMS on delivery was 0.93 ($p < .001$) and of sourcing on delivery was 0.18 ($p > .05$). In addition, β coefficient of LMS on quality was 0.98 ($p < .001$) and of production on quality was 0.17 ($p > .05$). This could explain the insignificant mediating effect of SC practices on the aforementioned LMS-OPMs relationship.

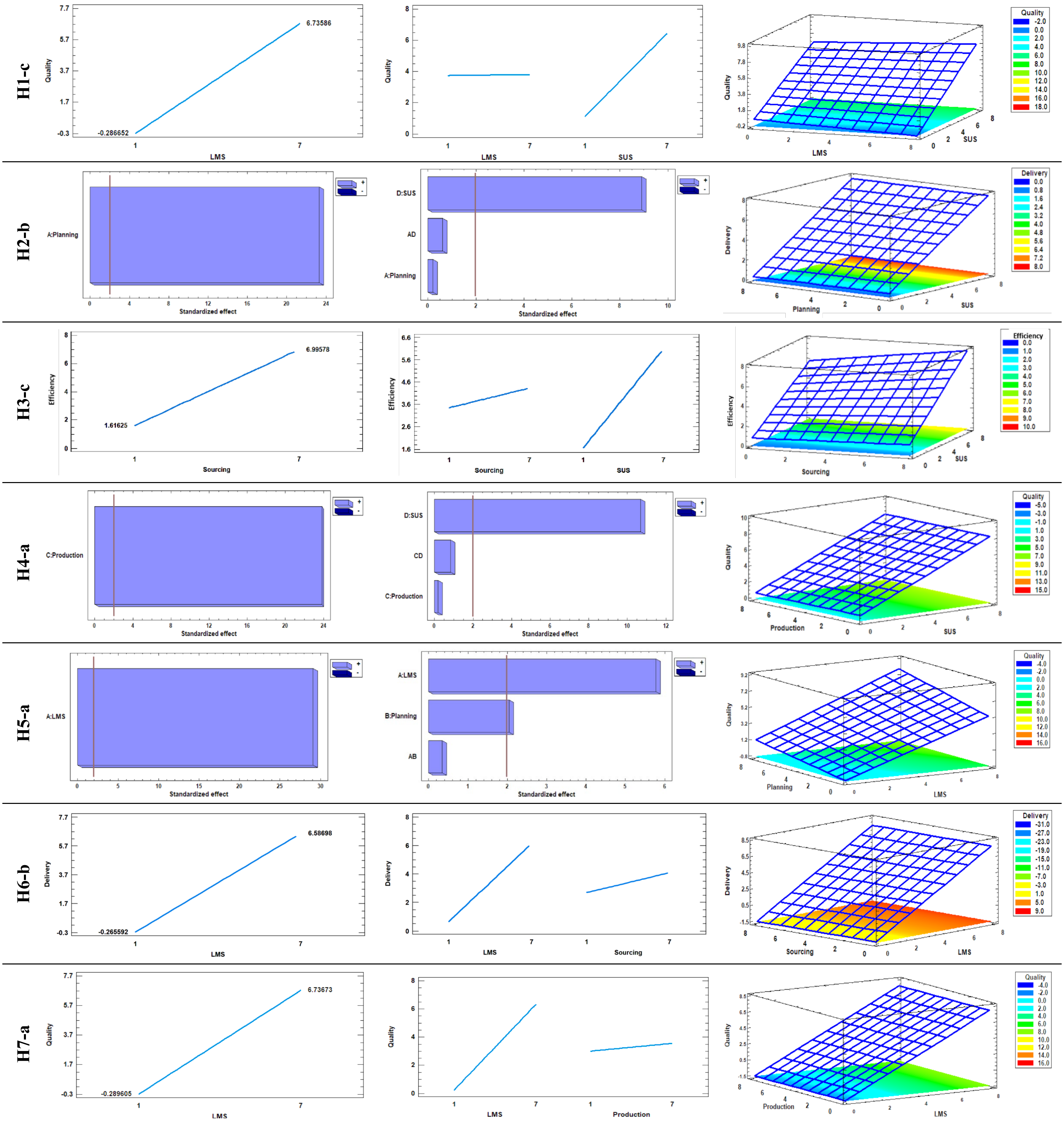

Figure 1. Visualization of significant mediation effects through Pareto Charts, direct and indirect effects plots and Response Surfaces

As it was shown in the main effects plots, no significant change was noticed regarding LMS in presence of sourcing and production. This is illustrated as well by the response surface where the quality and the delivery performance had the same trend at low and high level of sourcing and production respectively while implementing LMS. This means that the SC practices (sourcing and production) does not have any significant mediating impact on improving the performance.

Similar results were found in the literature regarding the positive association of Supply chain practices and lean practices (Inman & Green, 2018). Moreover, JIT and TQM programs are designed to reduce waste and provide products with high quality in less delivery time (Green et al., 2019; Marodin et al., 2019). Thus, the implementation of TQM can improve the on-time delivery by reducing the delivery delay caused by the quality control, rework and repair (Chen, 2015). Furthermore, within supply chain and LMS practices in the automotive industry, firms usually pursue continuous training sessions for employees, manage planned maintenance to expand their equipment effectiveness, the fact that will increase the productivity and improve production, quality and delivery performance. Moreover, SC practices plays a primary role in mediating LMS-OPMs relationship since they were found to have a major impact on the external operational performance (i.e. delivery, financial performance) (Prajogo et al., 2018).

6. Conclusion

6.1. Theoretical and Managerial implications

In this research, an empirical evidence was presented focusing on how the implementation of LMS, Supply Chain and Sustainability practices is linked to the improvement of the OPMs (quality, delivery, efficiency) of American and European automotive facilities. A questionnaire was developed and validated by practitioners. 94 managers have been questioned and have filled the survey. The results confirmed the mediating effect of sustainability practices on the relationship between supply chain practices and the studied OPMs, and between Lean and OPMs. On the other hand, LMS was found to positively affect OPMs through supply chain practices except for sourcing and production practices that weren't acting as mediators of LMS-delivery and LMS-quality relationships. This paper offers to the specialists some findings that may help them to improve their operational and financial performance, namely the quality, delivery and efficiency, through optimization and mutual implementation of Supply chain and Sustainability practices without neglecting the profitable LMS tools and techniques.

6.2. Limitations and future research

Some main issues and limitations have been highlighted for further improvement of the study. First, the sample size used in this research is small (94 automotive industries). After this pilot study, further analysis must be done by investigating industries in the automotive sector from different emergent economics countries (i.e. China, Russia, India, etc.) and with a larger sample size to validate the hypotheses decisions and to carefully analyze the results that may provide some additional insights. Second, this paper was focused on the automotive facilities. Therefore, expanding the research on other production sectors would be interesting.

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